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USASRDL Technical Report 2245

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WIND-DATA-ACQUISITION SYSTEM

by

Ronald W. Waite

December 1961

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

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Abstract

The wind-data-acquisition system is a laboratory, experimental equipment designed to accept wind information from up to 15 dual-channel wind sensors, instantaneously sample and convert this information to digital form, and enter it onto a punched paper tape in a format suitable for entry into an LGP-30 computer.

The results of tests carried out on the equipment indicate that it can be a very valuable research tool for conditions where it is desirable to obtain numerous data samples from various points and act on the data, using digital-data-handling techniques.

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WIND-DATA-ACQUISITION SYSTEM

PURPOSE

The purpose of this report is to describe, and present recommendations for, the use of an analog-to-digital converter and multiplexer which accept multiple inputs from various wind sensors and enter weighted values onto punched paper tape. (Figures 1 through 9 are different views of the system.)

BACKGROUND

In the past, measurements of wind speed and direction were performed by using various types of anemometers as sensors, with voltmeters and recording oscillographs to receive and record the outputs. Using the voltmeter method, only one sensor could be observed at a particular instant in time; and the value received was subject to human as well as equipment error which, in the case of wind gusts, could be considerable. Another method, that of utilizing recording oscillographs, was far better for recording actual instantaneous wind values; however, the system was adequate only for the observation of a single point or at most only a few points in the wind field.

In early 1960, personnel of the Meteorological Division of USASRDL held discussions to determine the feasibility of using digital-data-handling techniques in the acquisition of wind data. It was suggested that these techniques could be used as a substitute for and/or supplement to the present analog techniques. The two features affording the main advantages for using the digital-handling methods would be that instantaneous wind vectors could be obtained for numerous points of a wind field; and the output, instead of having to be manually evaluated, would be in a format compatible to a suitably programmed general-purpose digital computer (in this case, Royal McBee's LGP-30). Thus, by using the digital-handling techniques, a great deal of time could be saved in the tedious evaluation and averaging of wind values from numerous data samples.

It was decided at these discussions to include a digital system in the tests being conducted under the program for low-level winds for missiles. This program includes a series of tests of various types of wind-measuring equipments and evaluation techniques to determine the optimum system to be used in the prediction of a particular surface condition near a missile-launch site. Therefore, using design criteria from this program, technical requirements for a "commercial standard wind-data-handling subsystem," later called "wind-data-acquisition system," were prepared. In July 1960 a purchase order was placed with C. G. Electronics Corp. of Albuquerque, New Mexico (a subsidiary of Gulton Industries), for two such units to be delivered in October 1960. This system was to be used as a backup and supplementary system for a more sophisticated system being built concurrently by Stavid Division of Lockheed Electronics. (The latter system is described in a report entitled, "Converter, Analog to Digital CV-1043( )/GM," now being prepared.) The two systems are now in operation at the USASRDL wind range in Belmar, New Jersey.

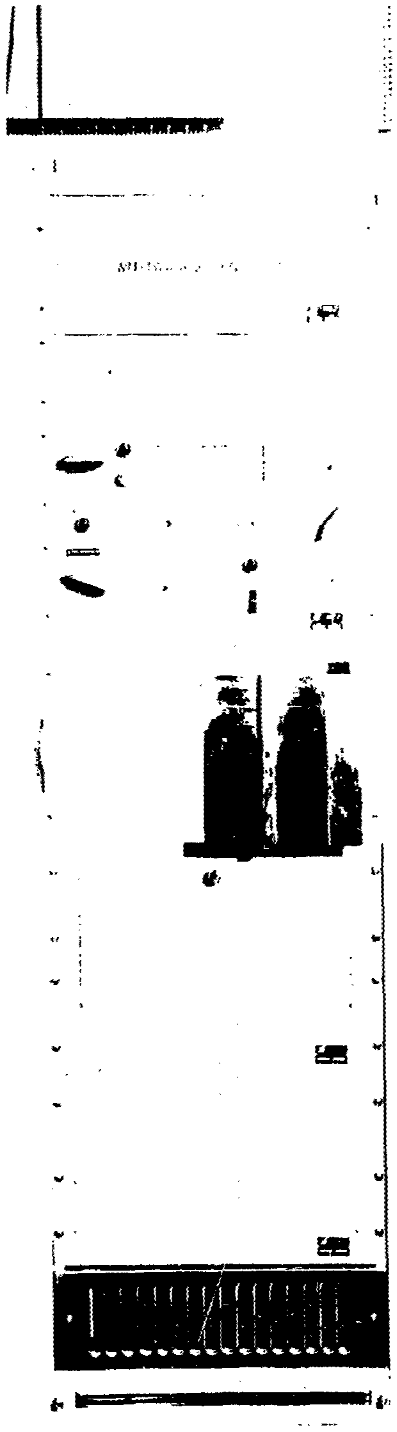


Fig. 1. Wind Data Acquisition System, Front view, showing complete unit.

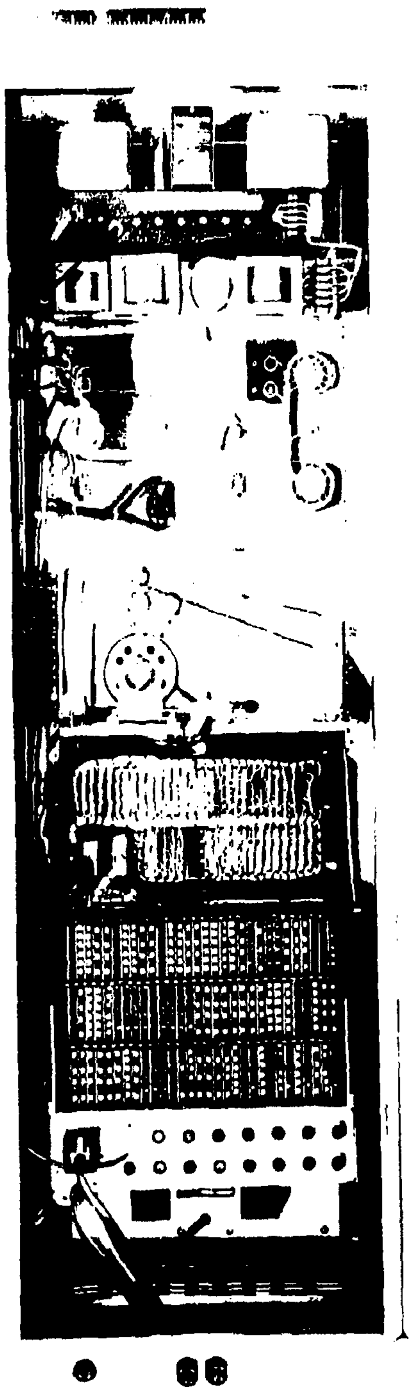


Fig. 2. Wind Data Acquisition System. Rear view, showing complete unit.

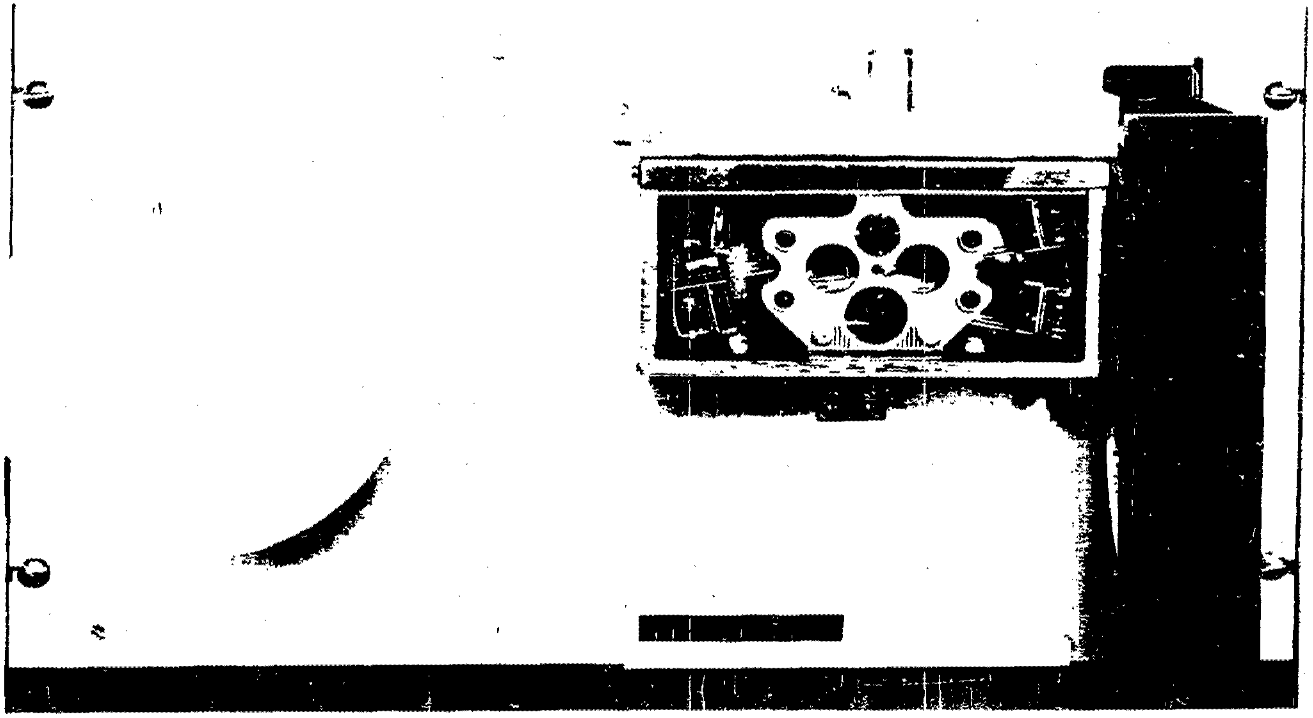


Fig. 3. Wind Data Acquisition System. Front view, showing punch mechanism.

Fig. 4. Wind Data Acquisition System. Front view, showing analog to digital converter section with cover plate removed.

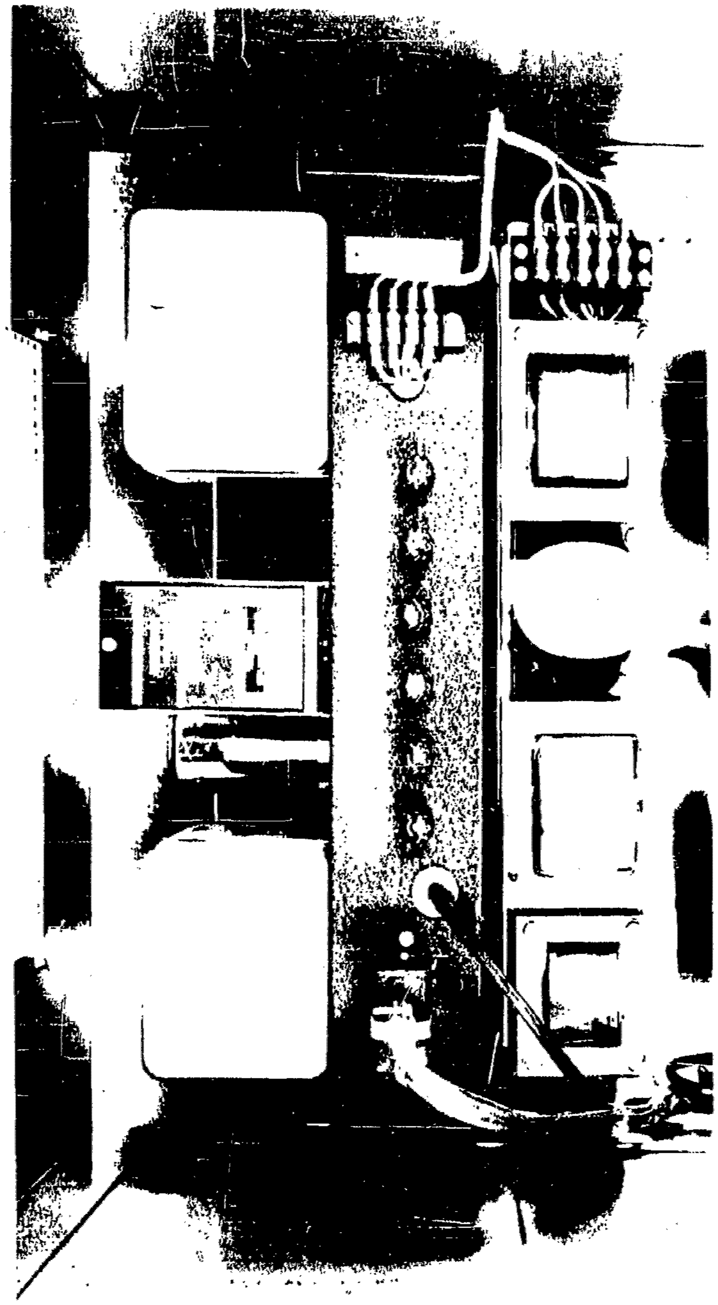


Fig. 5. Wind Data Acquisition System. Rear view, showing power supply.

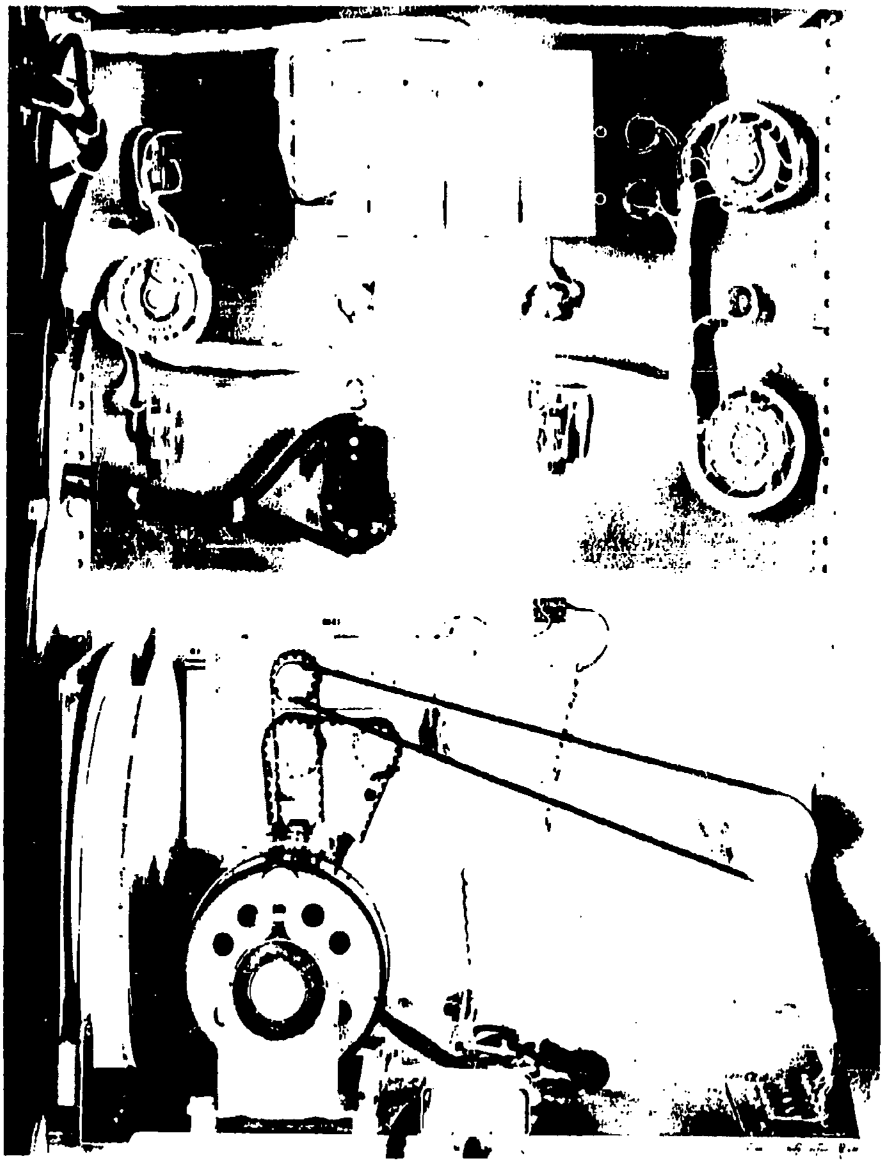


Fig. 6. Wind Data Acquisition System. Rear view, showing punch mechanism and control panel.

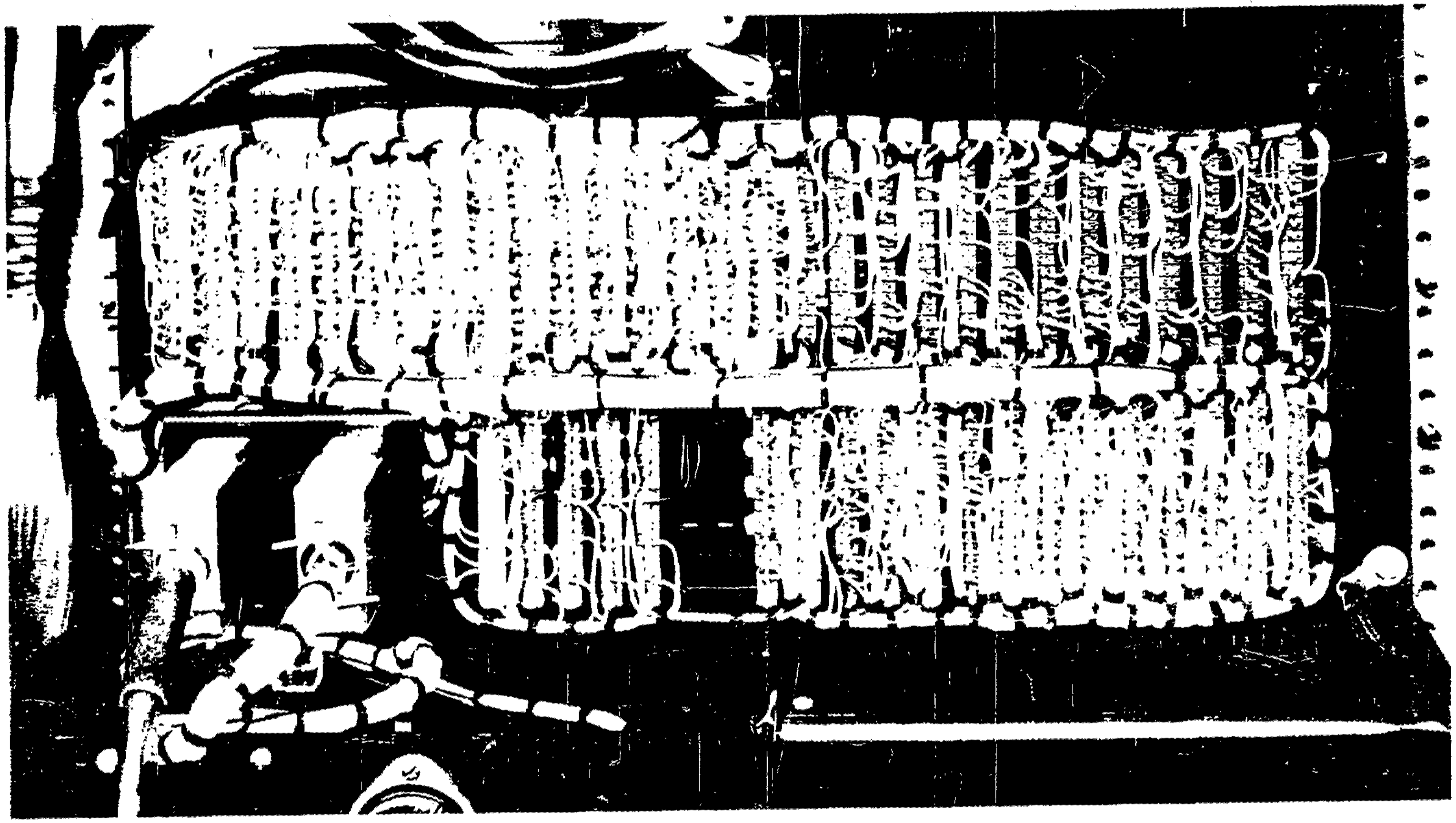


Fig. 7. Wind Data Acquisition System. Rear view, showing analog to digital converter

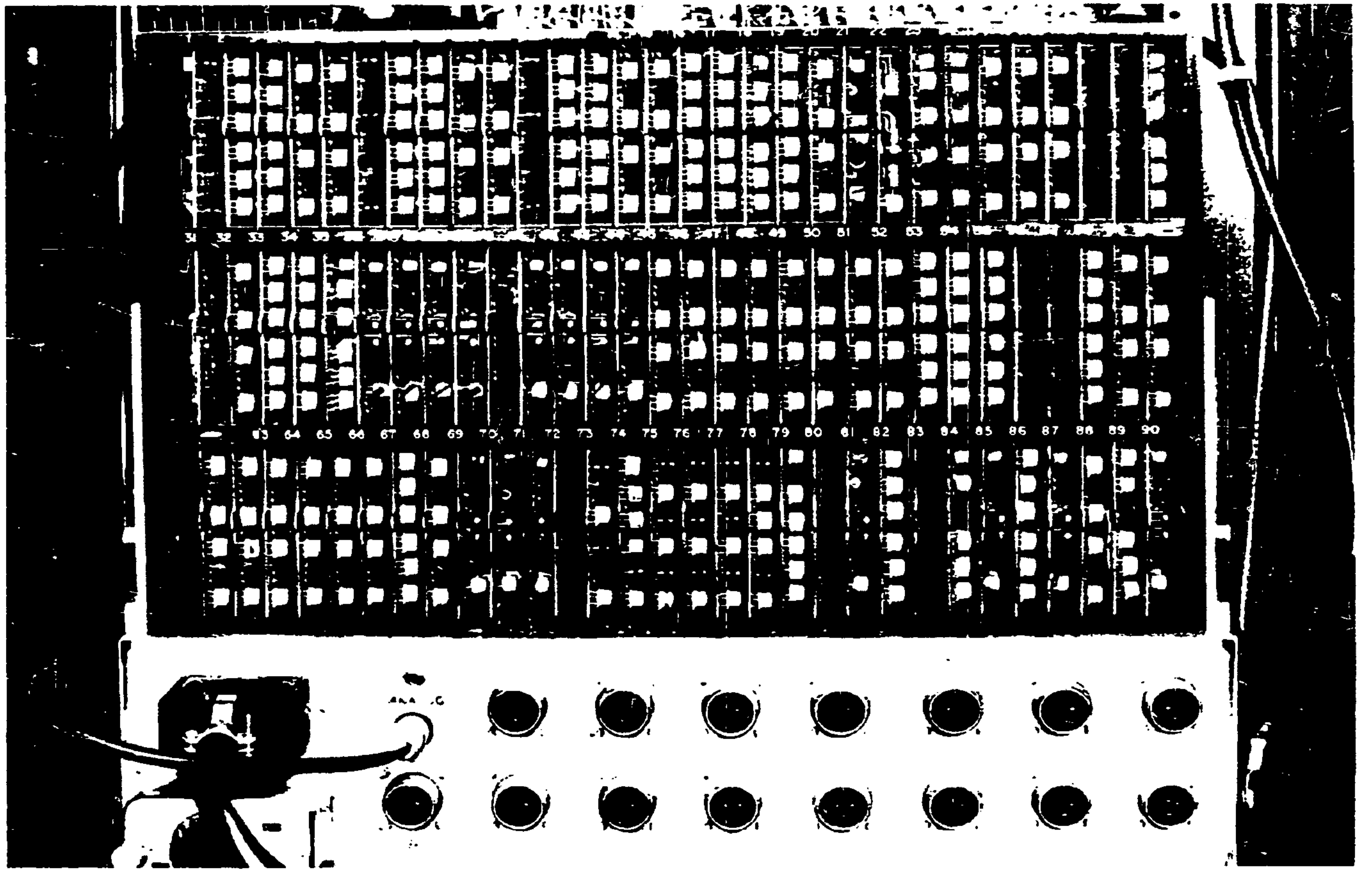


Fig. 8. Wind Data Acquisition System. Rear view, showing logic board and connector panel.

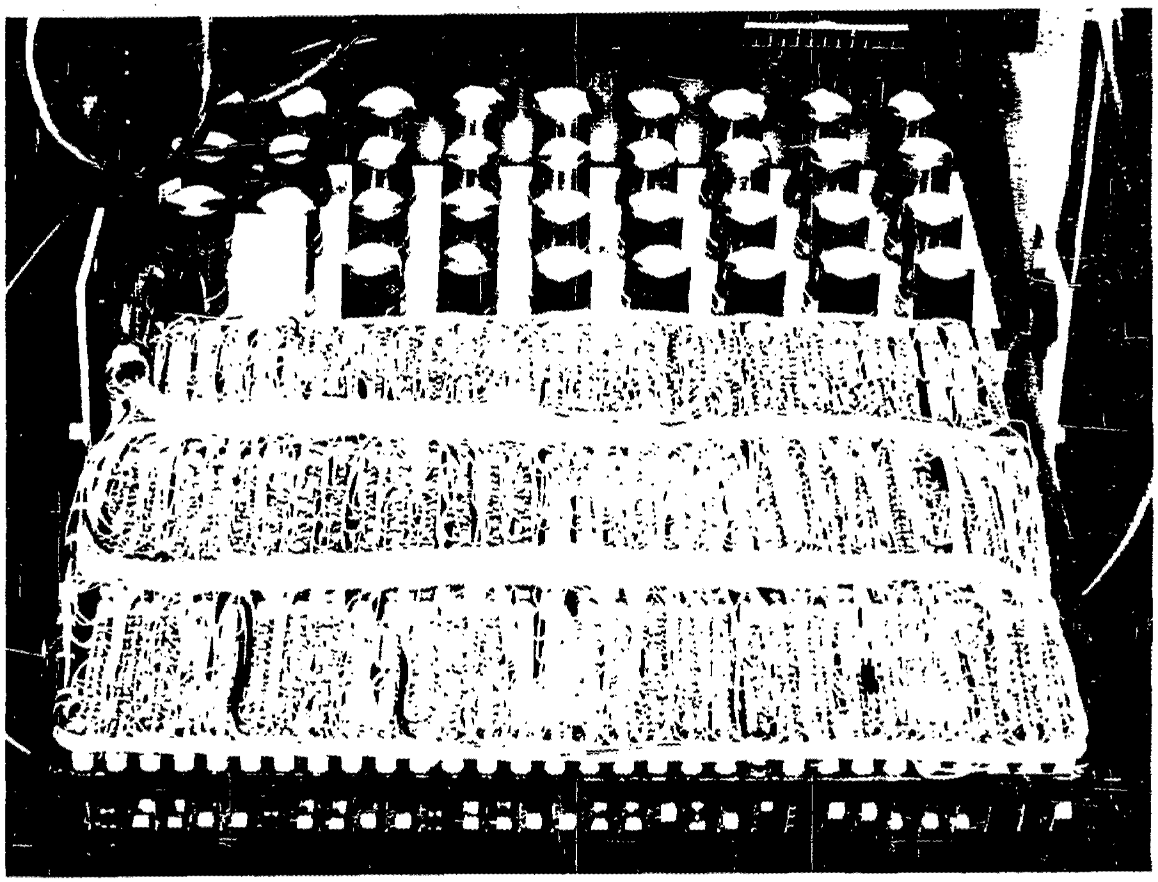


Fig. 9. Wind Data Acquisition System. Rear view, showing multiplexing relay section with logic board panel down.

DESCRIPTION

General

The basic subsystem to be used during the tests consisted of those components shown in Fig. 10. The wind sensor can be any unit that will give a voltage of approximately ±6 volts per ±100 miles per hour wind-vector speed. The output tape of the punch is in six-level Flexowriter code. An electric typewriter is both input and output for the LGP-30 computer mentioned previously (Fig. 11).

The wind-data-acquisition system (Fig.12) is designed to simultaneously sample up to 30 data channels (15 two-channel sensors), and digitize the analog data in serial form. A front-panel switch selects the repetition rate of the messages. The operator may select the number of sensors to be scanned or can select a single channel for observation. The output message is punched on a paper tape by a 60-character-per-second punch. The tape will contain a series of wind-speed values, in miles per hour to the nearest tenth, together with prefix and suffix characters in six-level binary coded decimal form suitable for entry into an LGP-30 general-purpose digital computer. (Figure13 shows a typical message.) A secondary output is the visual display on the front panel which can monitor the sampled wind vector of any one channel of a sensor.

Operation

The system has two modes of operation: manual and automatic. In the automatic mode the sampling and conversion cycle is initiated by a master timer, while in the manual mode the cycle is initiated by an operator using a front-panel control. The number of sensors to be sampled in any message is limited by the speed with which the punch can operate. In the case of the 60-character-per-second punch, only three sensors can be scanned and recorded every second. The selectable record rate intervals are 1, 2, 3, 6, 12, and 60 seconds per message.

When the system is initiated by the timer (see Fig.12), a 40-kc oscillator manufactured by Philamon Corporation, the 30 dump relays (mercury-wetted) are closed, allowing data from the 15 sensors to be stored in the sample-and-hold circuits. These circuits consist of an R-C combination having a time constant of ten milliseconds. During this sample time (approximately 100 milliseconds) the prefix characters (Fig.13) are entered onto the tape by command from the interlock gate. At the end of the sample time, the dump relays are opened, disconnecting the inputs; and the multiplexer relays activate the sample-and-hold circuit of the first data channel. This circuit is then connected to the analog-to-digital converter section through a high impedance, unity gain amplifier. The signal voltage is measured by a voltage comparator in binary decimal coded form. In approximately 100 microseconds the A-D converter has transformed the wind-vector voltage value into a four-level binary coded decimal (B.C.D.) representation of miles per hour to the nearest tenth. Following this function, the four-level B.C.D. code is changed to six-level Flexowriter code by means of a diode coding matrix. Following an appropriate time interval, which is controlled by the single-shot command chain circuit (see Fig.12), the data are fed to the write gates through buffer storage.

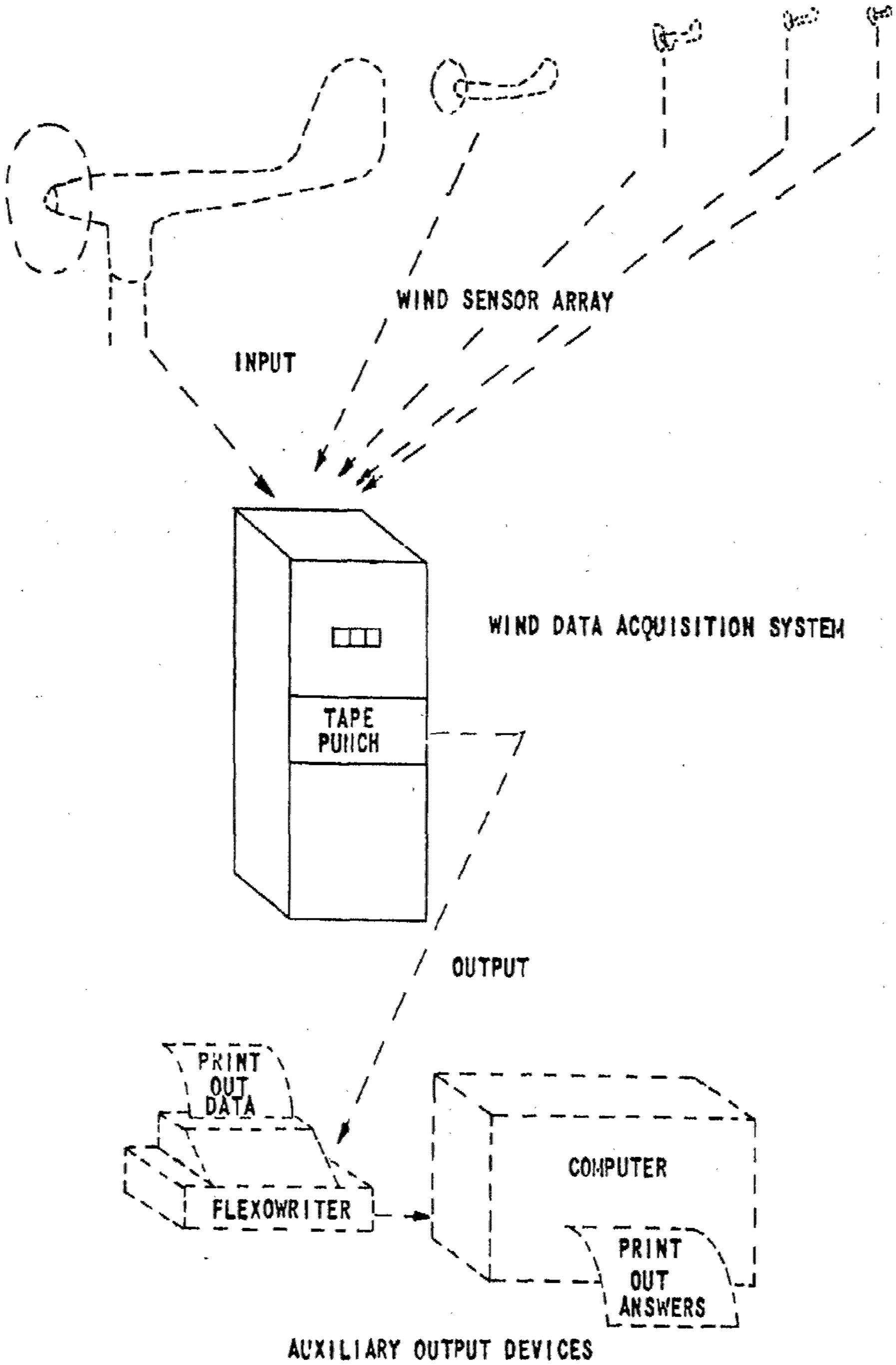


FIG. 10 WIND DATA CONVERSION SYSTEM

Symbol	Code x82 41y
Lower case	000 010
Plus sign	100 101
Minus sign	100 011
Conditional stop	010 000
Space	100 001
Carriage return	001 000
0	000 001
1	000 011
2	000 101
3	000 111
4	001 001
5	001 011
6	001 101
7	001 111
8	010 001
9	010 011

Tape sample

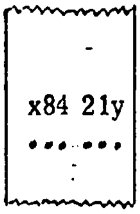


Fig. 11. LGP-30 Computer Code Used in Messages

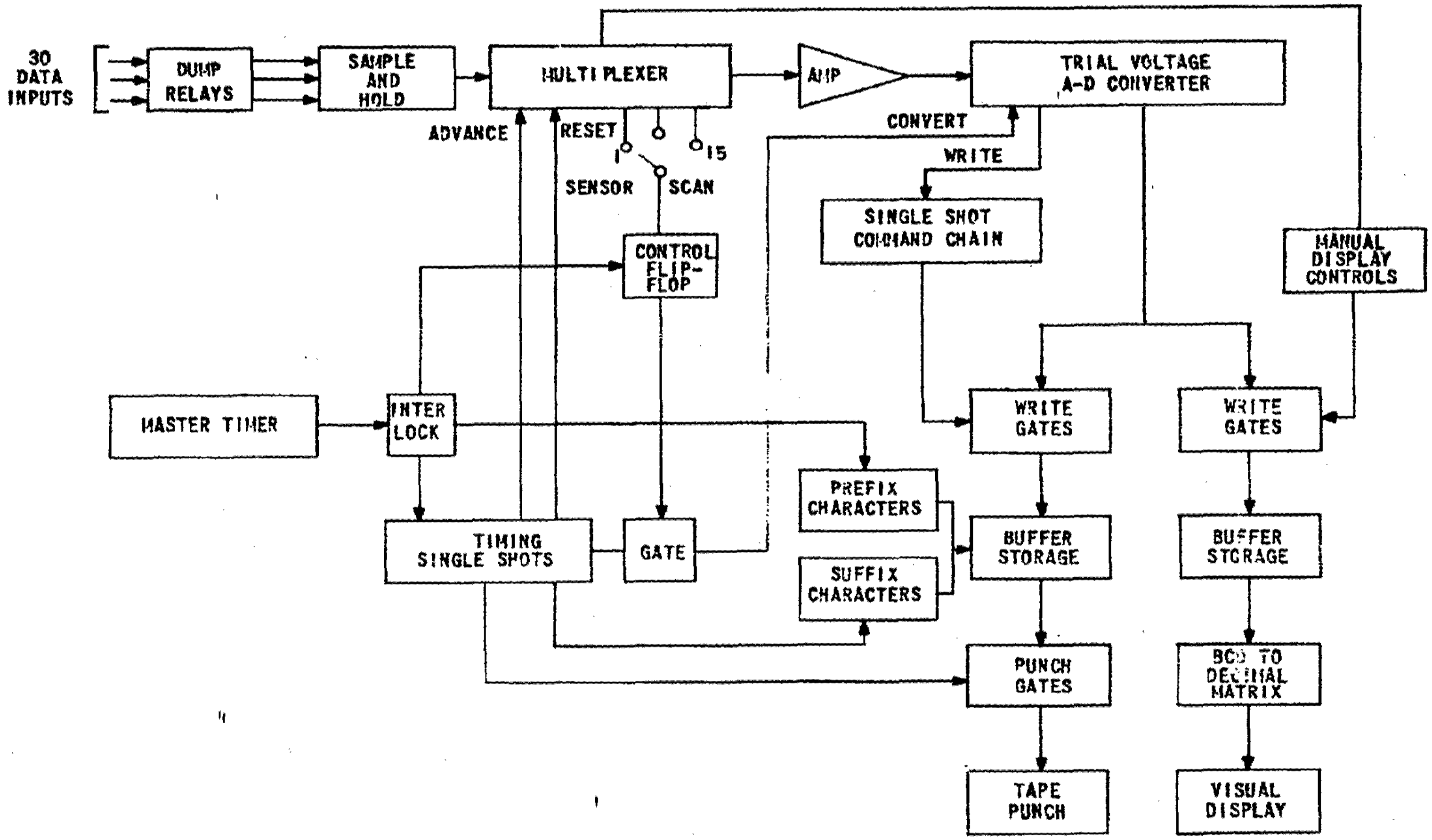
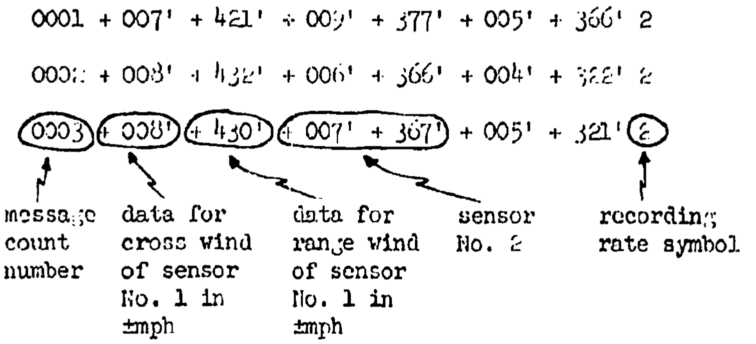


FIG. 12 WIND DATA ACQUISITION SYSTEM BLOCK DIAGRAM

The following is the message format used on the output tape:

	Item	No. of Characters
prefix characters	1. Start of message (lower case)	1
	2. Message count number	4
	3. Data with sign	4 times number of channels sampled
suffix characters	4. Computer control character (conditional stop)	1
	5. Recording rate interval symbol	1
	6. Spare character (space)	1
	7. End of message (carriage return - line feed)	1

The following shows what is included in a typical message of three sensors recorded at two seconds per message:



```
0001 + 007' + 421' + 009' + 377' + 005' + 366' 2
0002 + 008' + 432' + 006' + 366' + 004' + 322' 2
0003 + 008' + 430' + 007' + 367' + 005' + 321' 2
```

Fig. 13. Wind-Data-Acquisition System Message Format

The numerical values obtained by this process are then punched out in serial form on a paper-tape punch. The multiplexer then steps to the next data channel and the cycle is again repeated. When the final channel is reached, as determined by the sensor selector switch on the front panel, the multiplexer is automatically reset and the coded suffix characters are then gated to the punch gate circuits and onto the paper tape. The system will then remain inactive until another record rate pulse is received from the master timer.

Controls (Fig. 14)

The output can be presented in two modes: the first and primary output mode is through a Tally, model 420, 60-character-per-second tape punch. The second output mode is an in-line numerical display for visual monitoring. This display may be operated in either of two modes: continuous monitoring of the data contained in the message format or displaying the data on command, holding this value indefinitely.

The sensor-scan switch enables the operator to select the desired number of sensors for a particular message.

The time-interval switch determines the rate at which data-recordings take place. The time-interval switch and the sensor-scan switch settings must be compatible with the punch speed. A caution plate is provided to assure this compatibility.

The single-channel-operation switch allows the operator to select one particular channel to be recorded instead of all the channels.

The message-reset button is merely a system-reset button which, among other functions, will reset the message count to 0000.

The manual read-out button, when used in conjunction with the time-interval switch, will allow the operator to initiate the recording cycle.

TESTS AND RESULTS

When the two systems were first received, many deficiencies were found in the output message. These consisted primarily of inconsistent and inaccurate wind values. These deficiencies were alleviated by the contractor by replacing the multiplexing relays with an improved type and by adjustment of the various logic control timing functions. Until these modifications and adjustments were made, consistent or valid test data could not be obtained.

The test procedure to determine the operational accuracy of the wind-data converter consisted of two sections: a static accuracy check and a dynamic operational check.

The static-accuracy check consisted of supplying to the converter various d.c. voltages from ±0.000 to ±5.874 volts, using a Kepco, model 5441, precision d.c. voltage supply and a Fluke, model 801, d.c. differential voltmeter. These voltages represented wind speeds from ±00.0 to ±99.9 miles per hour. The converter operated on the signal and presented an output message

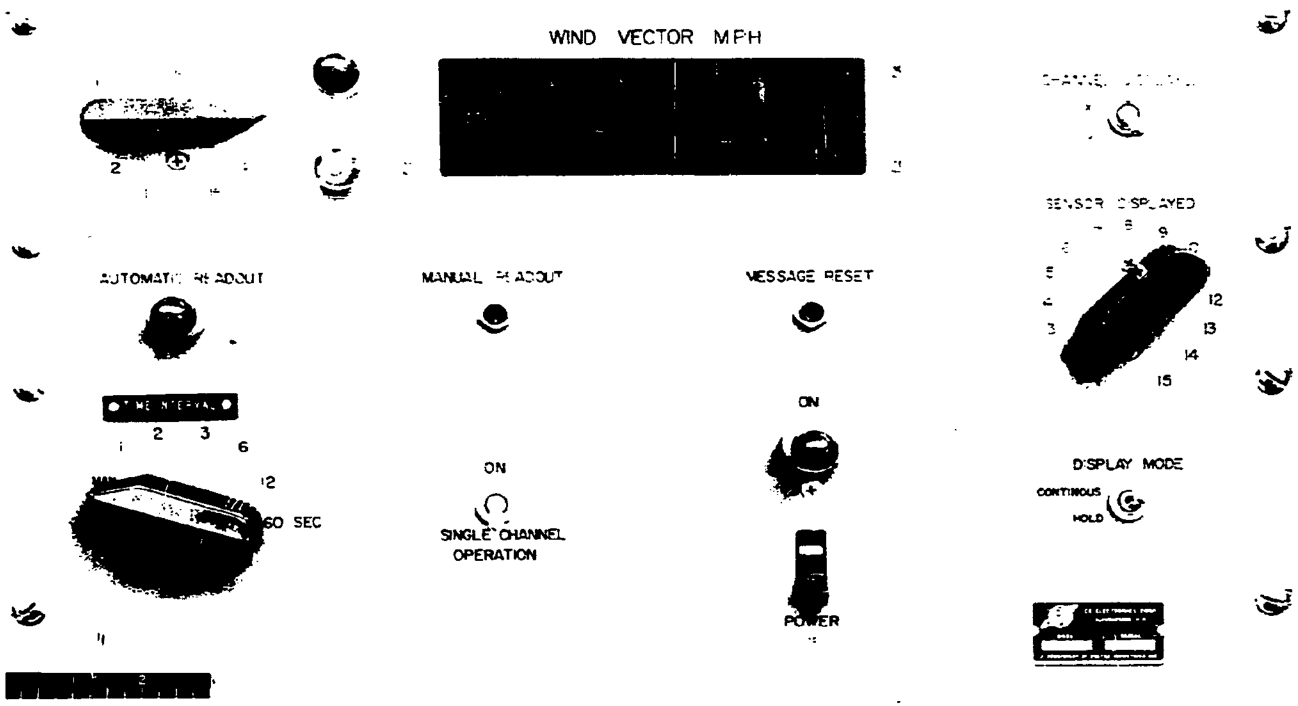


Fig. 14. Wind Data Acquisition System. Front view, showing control panel.

on the paper tape. Calibration voltages were supplied to one connector (one sensor) and subsequently to a number of connectors representing a number of simulated data channels. The simulated data were presented on the punch-paper tape which was reproduced in tabulated numerical form for evaluation.

The system accuracy was found to be dependent on many factors such as different contact-closure times for the multiplexing relays and A-D converter conversion error. The difference in recorded values between one channel and another was due to these factors. The greatest variation from channel 1 to channel 30 per sample was three counts, or 0.3 mph, with the average maximum deviation of about 0.2 mph. Variations in accuracy also occurred with changing input signals. At wind speeds up to ±40 mph, the variation from one channel of one sample to the next sample was ±0.1 mph, but these variations occurred infrequently. Above 40 mph the variation still remained at 0.1 mph, but its occurrence from one sample to the next was much more frequent. Another slight variation in accuracy occurs when a negative input voltage is introduced. The maximum deviation for this condition, however, is only -0.1 mph.

Tests were run at 105 volts and 125 volts, with no deterioration of results.

Figure 15 gives an illustration of a calibration-accuracy test run at 115 volts for six different input signals. The data alternate channels, since this gives the maximum change from one channel to the next and thus the greatest chance for error. The input voltages are in proportion to ±5.874 volts = ±100.0 miles per hour, as shown below.

Wind speed (mph)	Input voltage (volts)
100.0	5.874
80.0	4.699
40.0	2.350
20.0	1.175
10.0	0.587.

These values are true only for an input impedance of 100K ohms.

The dynamic accuracy check consisted of replacing the precision voltage with a set of wind sensors and observing the output message form. The basic reason for this test was to observe the consistency and compatibility of the sensor array and the converter.

Numerous long data samples (200 messages per sample) were observed, and the compatibility of the system was adjudged to be good. The converter gave a true representation of the conditions present at the sensor. The consistency was determined to be good for a digital system with no error-checking or error-correcting circuitry. During the tests both units averaged about one error per 40,000 characters output. The error, when it occurred, was usually a sign or a conditional stop character.

During the tests it was determined, and also suggested by the contractor, that a calibration run should be made on the equipment biweekly, and any

```
 1x   1y   2x   2y   3x   3y   4x   4y   5x   5y   6x   6y   7x   7y   8x   8y   9x   9y  10x  10y  11x  11y  12x  12y  13x  13y  14x  14y  15x  15y
                                                           +80.0 mph
0001-000'+799'-000'+798'-000'+799'-000'+799'-000'+798'-000'+799'-000'+799'-000'+770'-000'+799'-000'+798'-000'+779'-000'+799'-000'+799'-000'+799'-000'+799'4
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                                                           +20.0 mph
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                                                           +10.0 mph
0001+099'-000'+099'-000'+099'-000'+099'-000'+099'-000'+099'-000'[illegible]'-000'[illegible]'-000'+099'-000'[illegible]'-000'+099'-000'+099'-000'-099'-000'+099'-000'+099'-000'
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                                                           +8.0 mph
0001-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'[illegible]'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'4
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0004-000'+079'-000'+079'-000'+079'-000'[illegible]'-000'+079'-000'+079'-000'+079'-000'+079'-000'-079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'4
0005+079'-000'+079'-000'-077'-000'+079'-000'+079'-000'+079'-000'+077'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'4
0006+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'[illegible]'-000'+079'-000'+079'-000'+077'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'
0007+079'-000'+079'-000'+079'-000'[illegible]'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'4
0008+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079'-000'+079

                                                           +4.0 mph
0001+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'4
0002+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000
0003+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'4
0004+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'4
0005-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039
0006-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'4
0007-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'4
0008-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039'-000'+039
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Fig. 15. Sample Calibration Run

conversion adjustments necessary be made at that time. This is necessary because of the normal aging process and the unequal environmental conditions persisting where the equipment is located.

The results of these tests confirmed that the system accuracy is satisfactory, since the errors were well within the applicable tolerance range. In most cases the equipment functioned more satisfactorily than was expected. In any case, the equipment is much more accurate than the wind sensors now in use and so will not add appreciably to the over-all system error.

CONCLUSIONS

The equipment, after the initial adjustment period, gave satisfactory performance. The original accuracy required by the technical characteristics was ±0.1 mph; however, during the tests it was found that some points fell slightly outside this region. It was felt that since these points were so infrequent and since they fell outside the usual range of measurement (in the 70- to 100-mph range), the equipment met the requirements.

Some trouble has occurred with the 60-characters-per-second tape-punch in one unit; however, this is due to a faulty part supplied by the punch manufacturer. When this part is replaced, the punch will function satisfactorily.

The equipment was turned over to personnel using the USASRDL wind range in May 1960, and it has been obtaining data since that time. During this period no trouble has been reported, and no maintenance has been performed other than the usual spot-check of conversion accuracy, and adjustment if out of range.

It has been found that the equipment performs more reliably when used frequently, and, after the initial break-in period, the components have aged or adjusted to the circuit in which they are placed.

It should be noted that, although the system operation given in the description is simple, there are a large number of electronic components involved. In the logical-control and analog-to-digital-converter sections, there are 136 circuit boards, each of which contains an average of four transistors with their associated circuits. When these are converted into possible error areas, the reason for the error rate becomes obvious.

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